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Top Quark Partners with Exotic Charge ($T_{5/3}$)

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Top Partners

- Heavy top partners are a common prediction of different theories
  - Couple to 3rd generation quarks
  - Solve hierarchy problem
  - Compatible with 125 GeV Higgs
    - See arXiv:1212.1380 (Int. J. Mod. Phys. A Volume 28 (2013) 1330004)

- Can be found in
  - Minimal Composite Higgs
  - Extra dimensions (KK gluons)

The $T_{5/3}$

- Top partner models include several particles
  - Focus on quark with charge 5/3
  - Typically the lightest

- Theoretical descriptions
  - ***Contino & Servant***, JHEP 0806:026 (2008)
  - ***Mrazek & Wulzer***, Phys. Rev. D 81, 075006 (2010)
  - More recently: **CERN-PH-TH/2012-323** (arXiv:1211.5663)

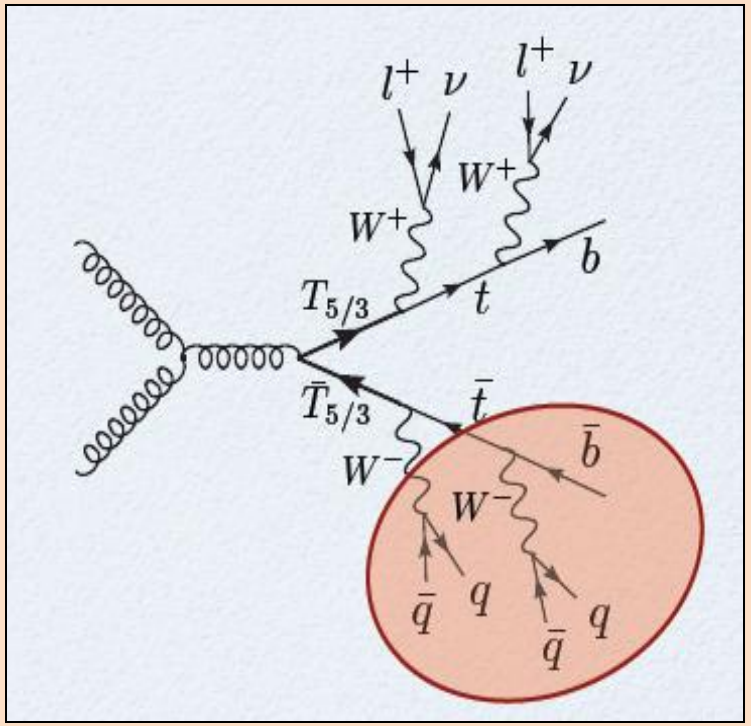
- Experimental results
  - **CMS-PAS-B2G-12-012** (8 TeV) excludes $M(T_{5/3}) < 770$ GeV at 95% C.L.
  - **ATLAS-CONF-2012-130** (7 TeV): 670-700 GeV depending on coupling
  - Published result: CDF (Phys.Rev.Lett.104:091801, 2010), 365 GeV

Model

- $T_{5/3}$ with $Q_e = 5/3$ and B with $Q_e = -1/3$ decay into W and top
  - Per Mrazek & Wulzer, B is typically more massive than $T_{5/3}$
  - Focus on $T_{5/3}$

- Most striking signature: same-sign dileptons

$$l^{\pm}l^{\pm} + 2b + 2\mathrm{W}$$



- The hadronically decaying $T_{5/3}$ can be reconstructed

Cross-Sections

NNLL cross-sections from HATHOR (arXiv: 1007.1327)

$M(T_{5/3})$	σ (8 TeV) [fb]	σ (13 TeV) [fb]	σ (33 TeV) [fb]
700	5.69e+01	4.41e+02	8.36e+03
800	2.08e+01	1.90e+02	4.20e+03
900	8.07e+00	8.80e+01	2.25e+03
1000	3.27e+00	4.30e+01	1.28e+03
1100	1.37e+00	2.19e+01	7.57e+02
1200	5.85e-01	1.15e+01	4.66e+02
1300	2.53e-01	6.26e+00	2.95e+02
1400	1.10e-01	3.47e+00	1.93e+02
1500	4.81e-02	1.96e+00	1.28e+02
1600	2.08e-02	1.12e+00	8.73e+01
1700	8.92e-03	6.53e-01	6.05e+01
1800	3.75e-03	3.83e-01	4.25e+01
1900	1.54e-03	2.26e-01	3.03e+01
2000	6.17e-04	1.35e-01	2.19e+01
2100	2.39e-04	8.03e-02	1.60e+01
2200	8.90e-05	4.81e-02	1.18e+01

Selection

- Two same-sign leptons
  - Tight ID and isolation
    - Similar to top quark leptons, but more attention to charge
  - p_T cut of order 30 GeV
  - Z-veto

- Jet multiplicity
  - At 8 TeV, count jets with $p_T > 30$ GeV
  - Raise this at higher energy

- H_T = scalar sum of p_T of selected leptons and jets

- ATLAS uses missing E_T and b-tagging

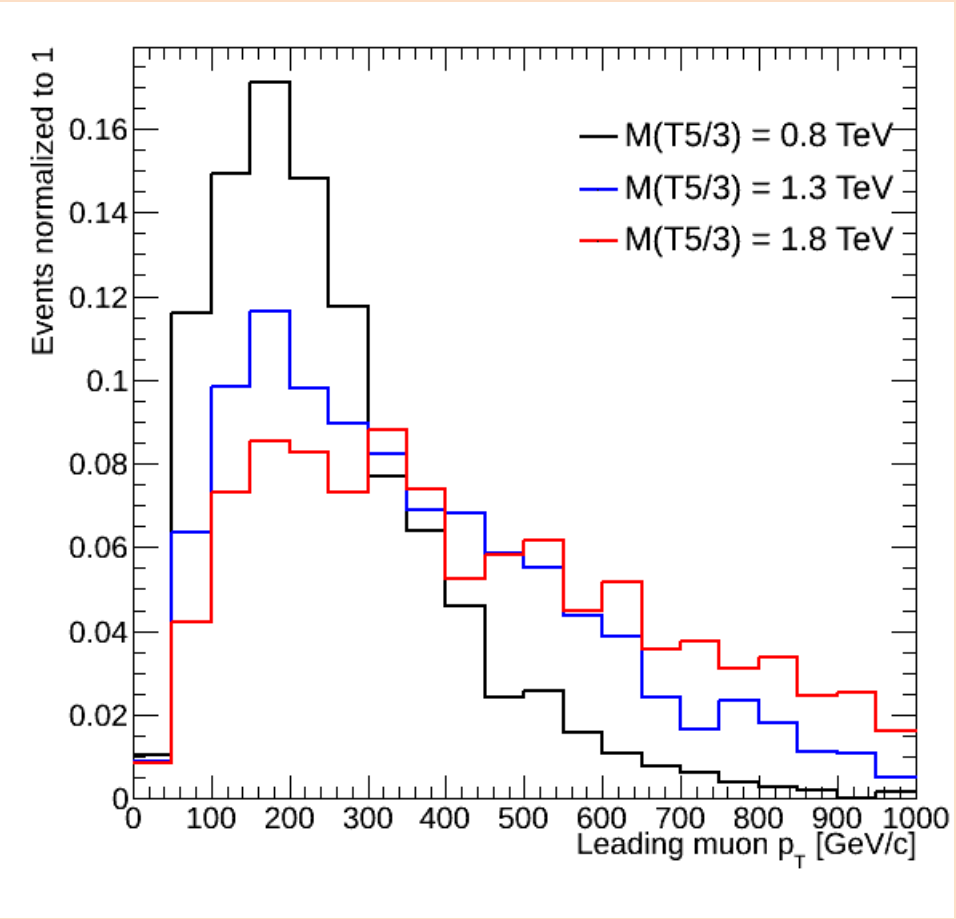
Background Determination

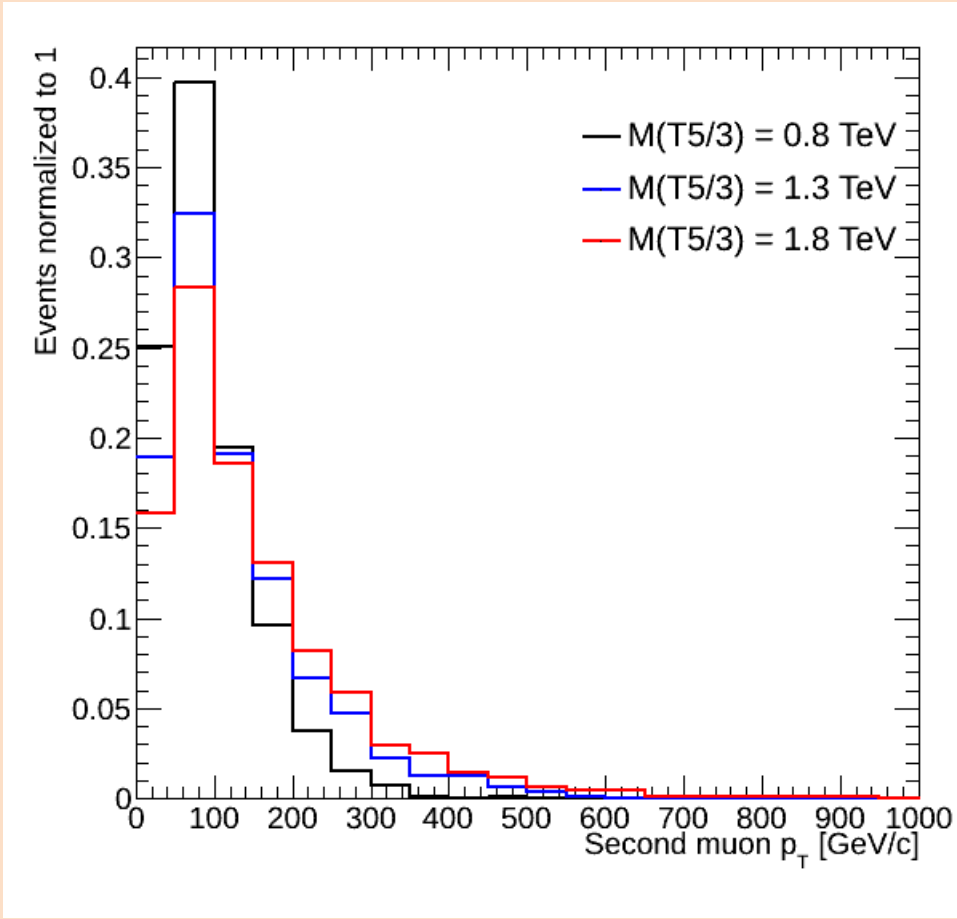
- Rare Standard Model backgrounds with prompt same-sign leptons
  - ttbarW, ttbarZ, WZ, ZZ, same-sign WW, WWW
  - Some already generated, the rest after the major backgrounds
- Backgrounds from charge misID (Z+Jets, ttbar)
  - Get misID probability from Z events, do analysis with opposite sign leptons and multiply
  - Data driven, but Monte-Carlo describes this well
- Non-prompt lepton backgrounds
  - Leptons misidentified as jets
  - Leptons from heavy flavors, decays in flight
  - “Fake rate” method (also known as “tight/loose”)

Tools

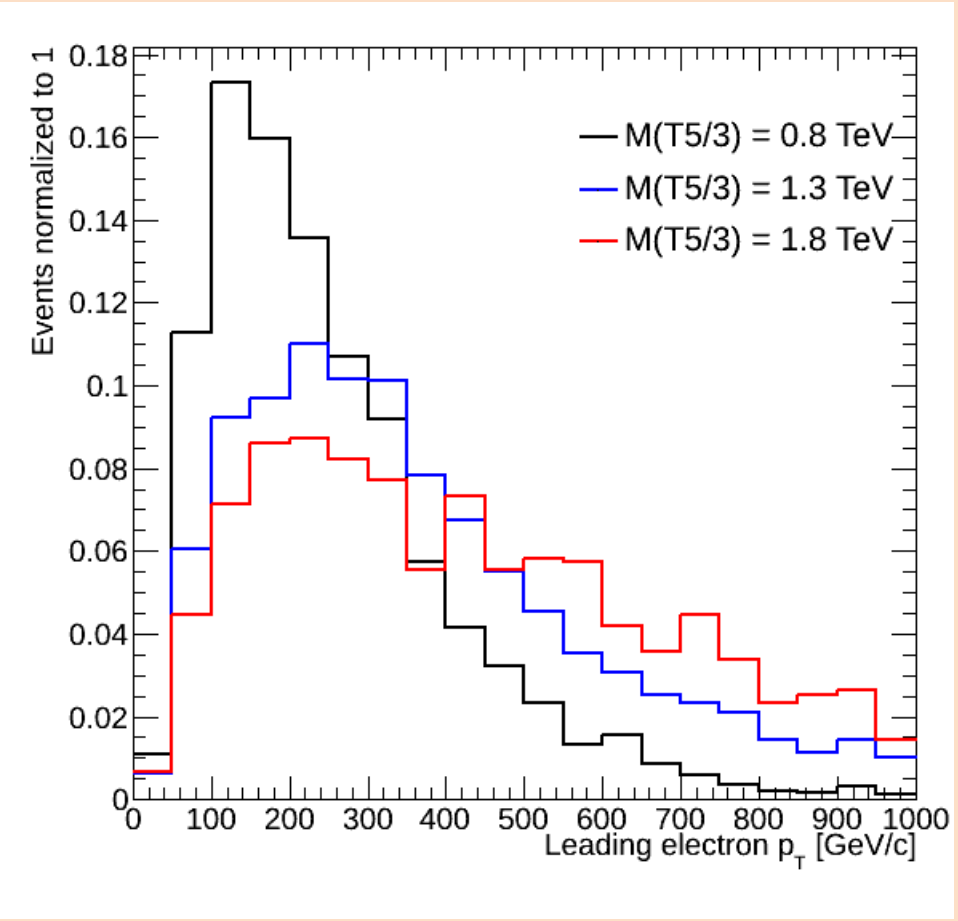
- Using the framework described in https://indico.bnl.gov/getFile.py/access?contribId=51&sessionId=2&resId=0&materialId=slides&confId=571
- MadGraph5 v1.5.8
- Simulation with Delphes3
  - Use parametrization cards from S. Padhi
- Processed on Open Science Grid
- RESULTS ARE PRELIMINARY!

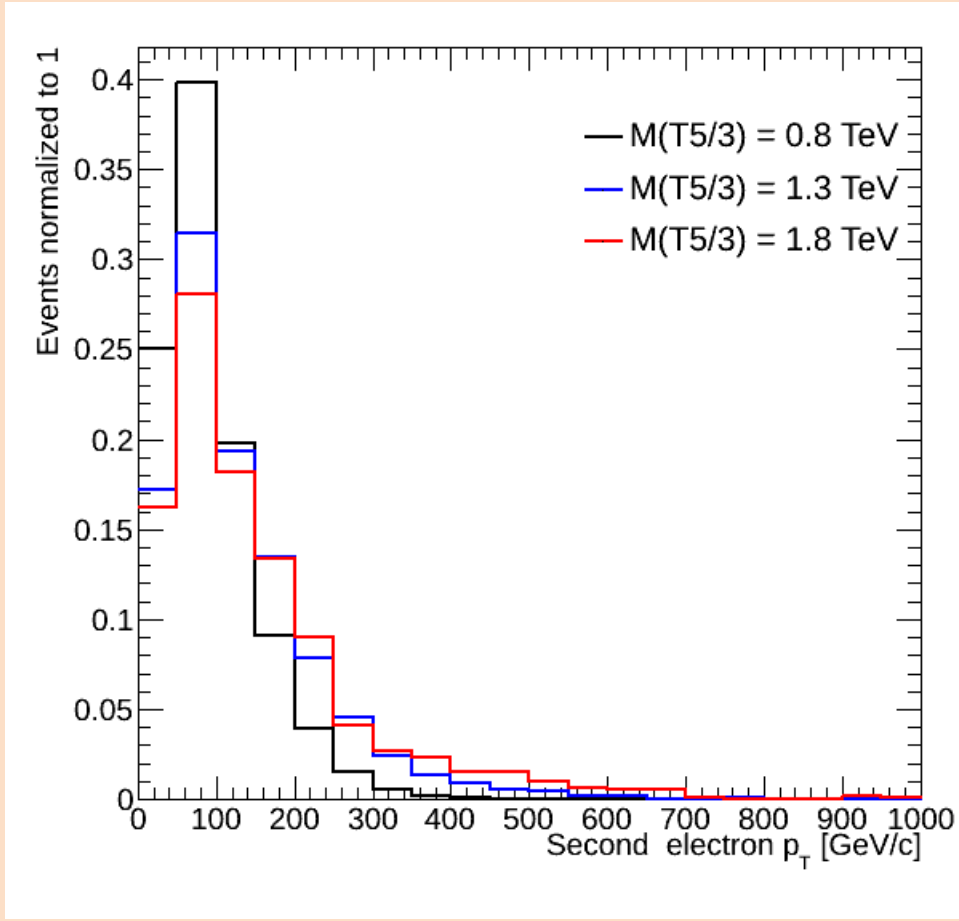
Muon p_T (33 TeV, 0 Pileup)



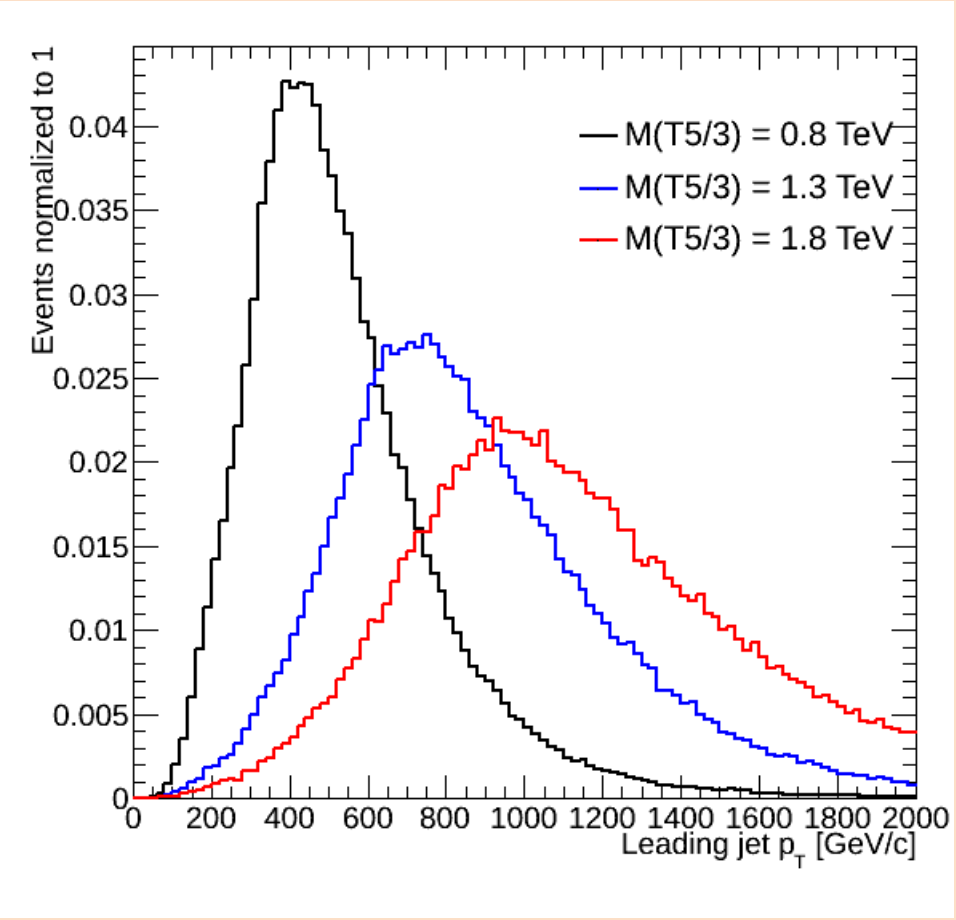


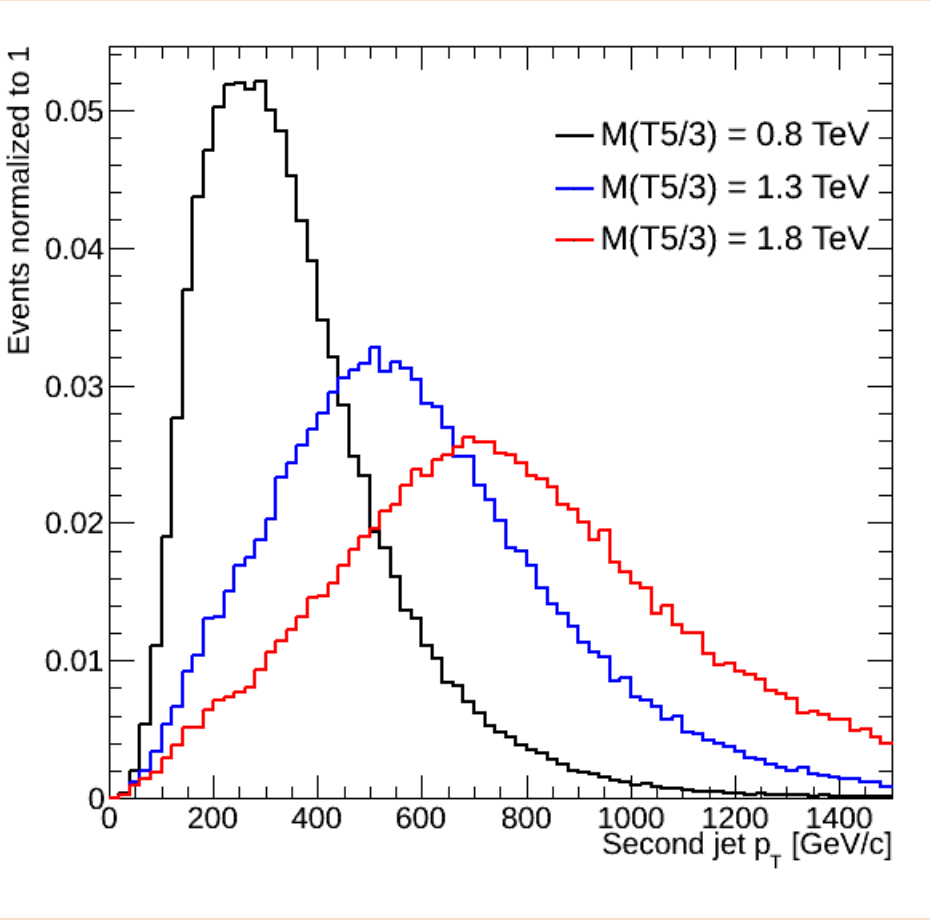
Electron p_T (33 TeV, 0 Pileup)





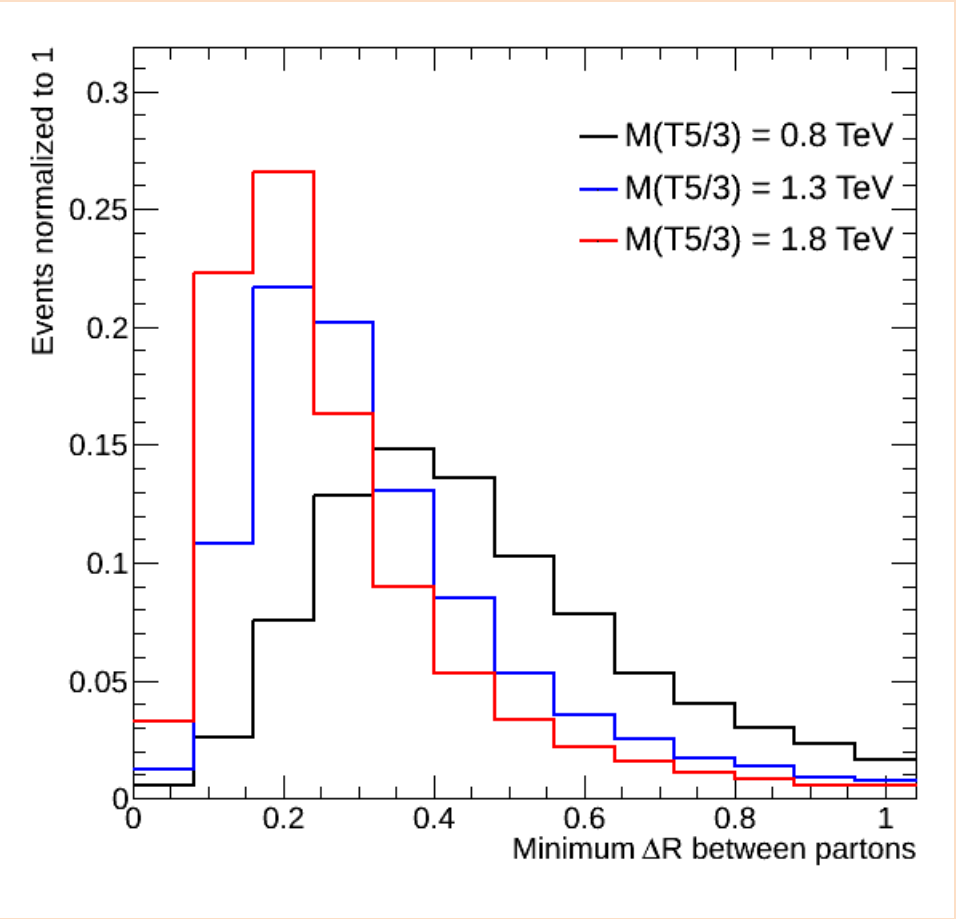
Jet p_T (33 TeV, 0 Pileup)





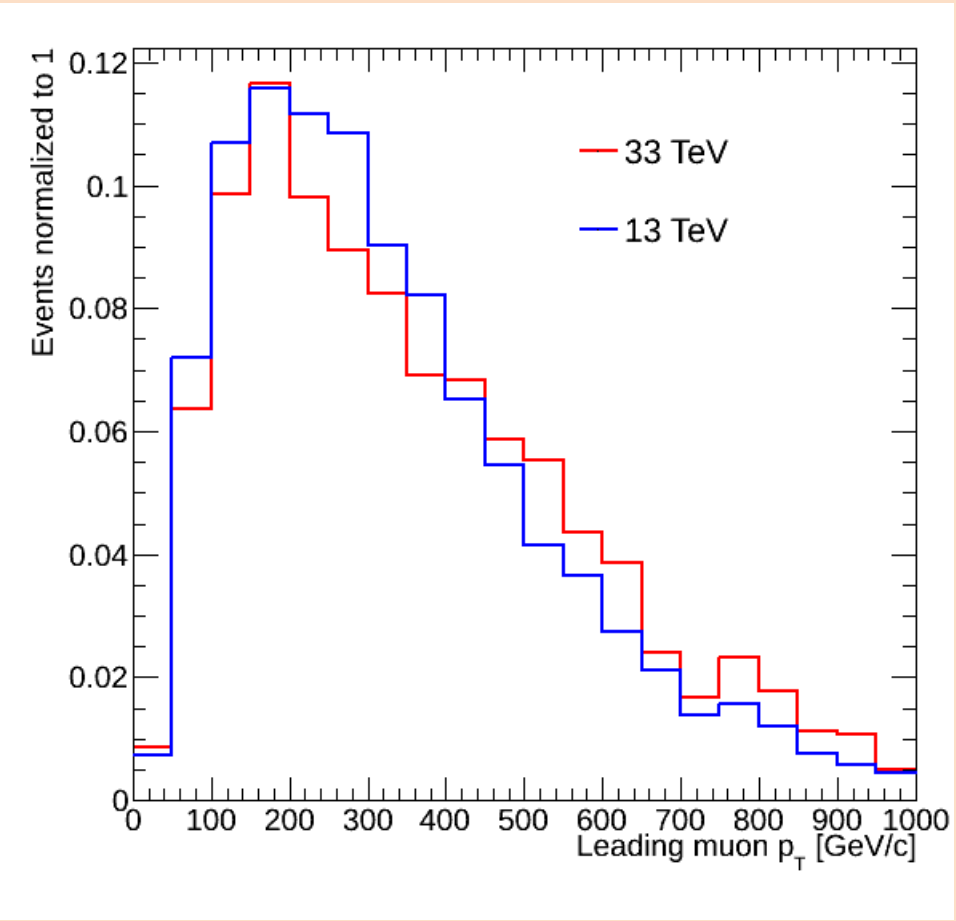
- Jet p_T is more distinct
  - Also, much higher

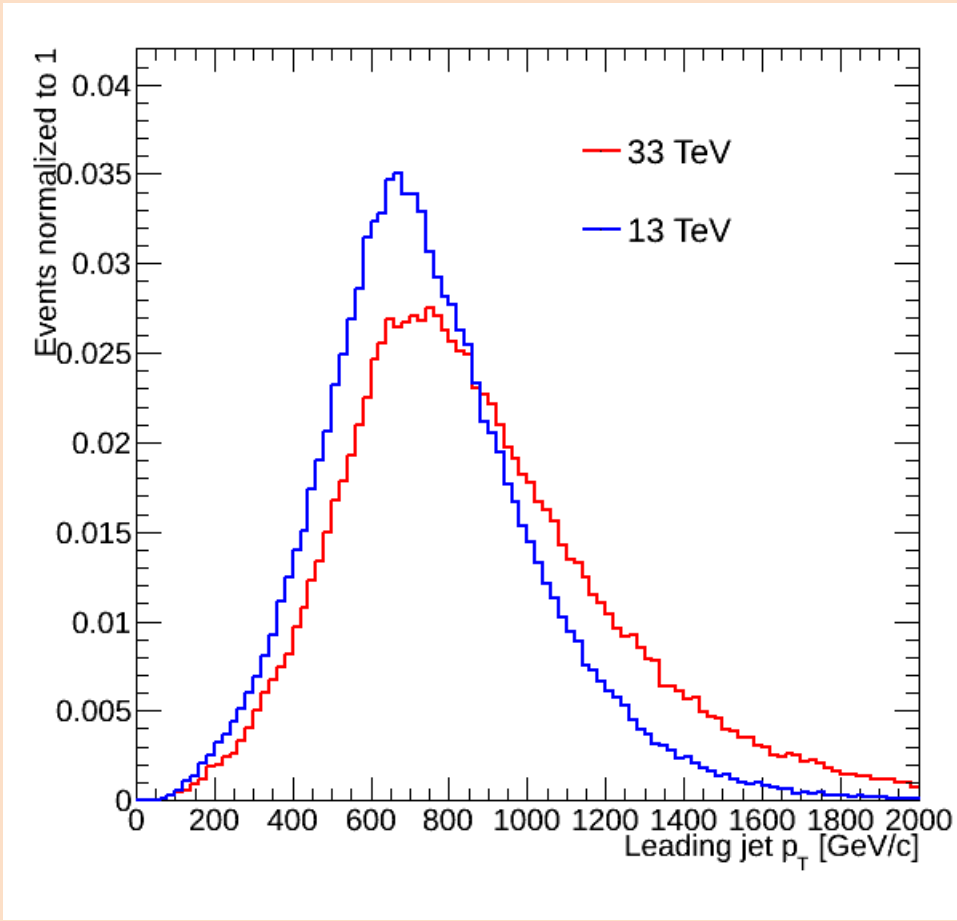
Boosted Objects



- Decay products of $T_{5/3}$ are boosted
  - More noticeable with the W
  - Effect increases with $T_{5/3}$ mass
- Consider dR between gen-level objects
  - Status 3 particles with PDG ID < 6 and p_T > 30 GeV
- Definitely need jet substructure techniques
  - Delphes EFlow objects

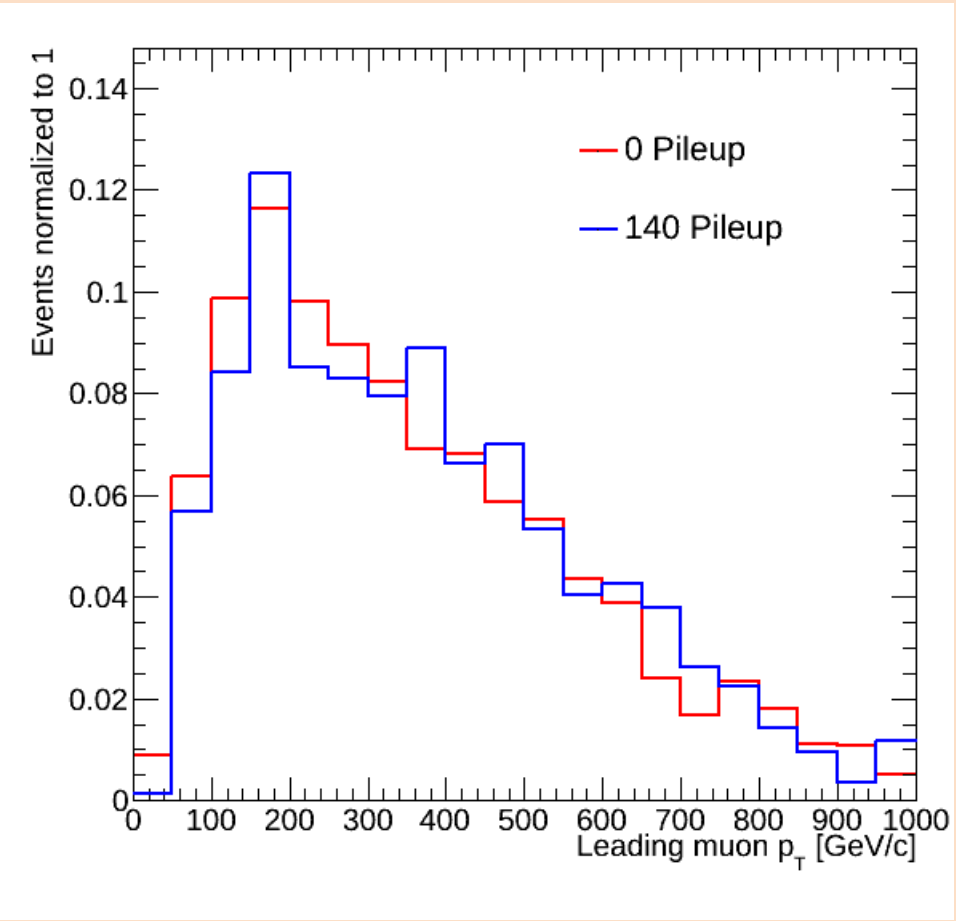
33 TeV vs. 13 TeV (M = 1300 GeV, 0 Pileup)

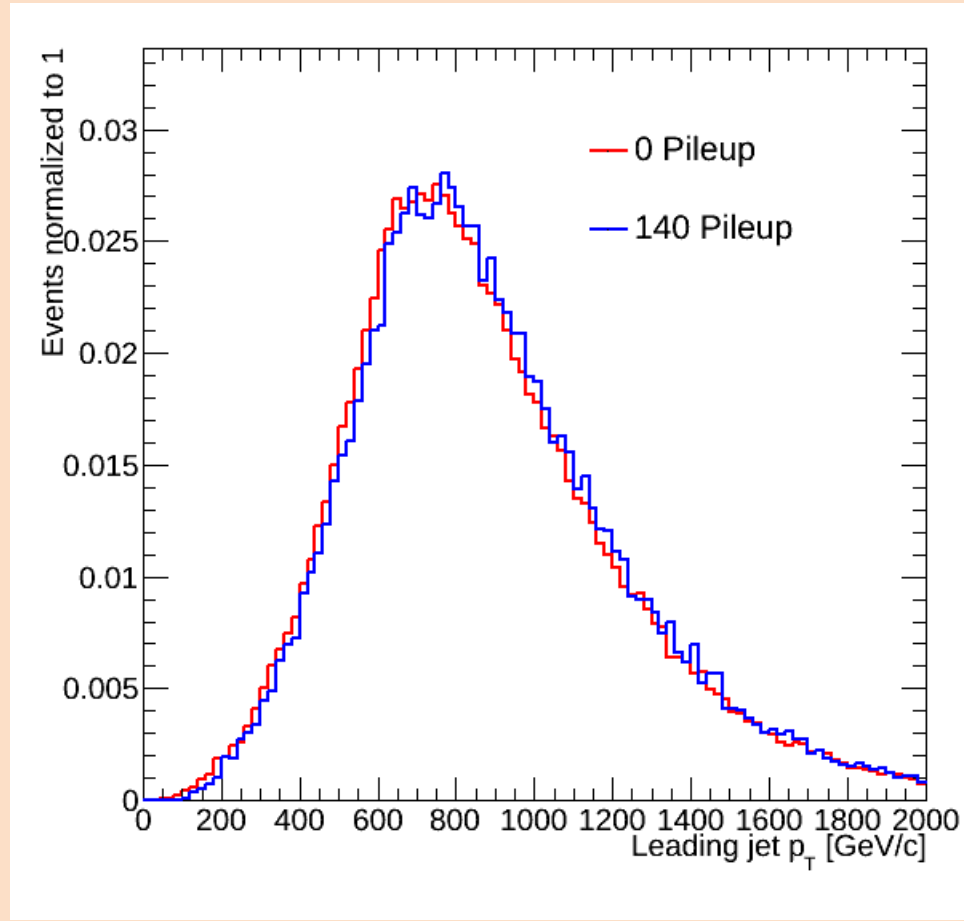




- $T_{5/3}$ is heavy, even for 33 TeV

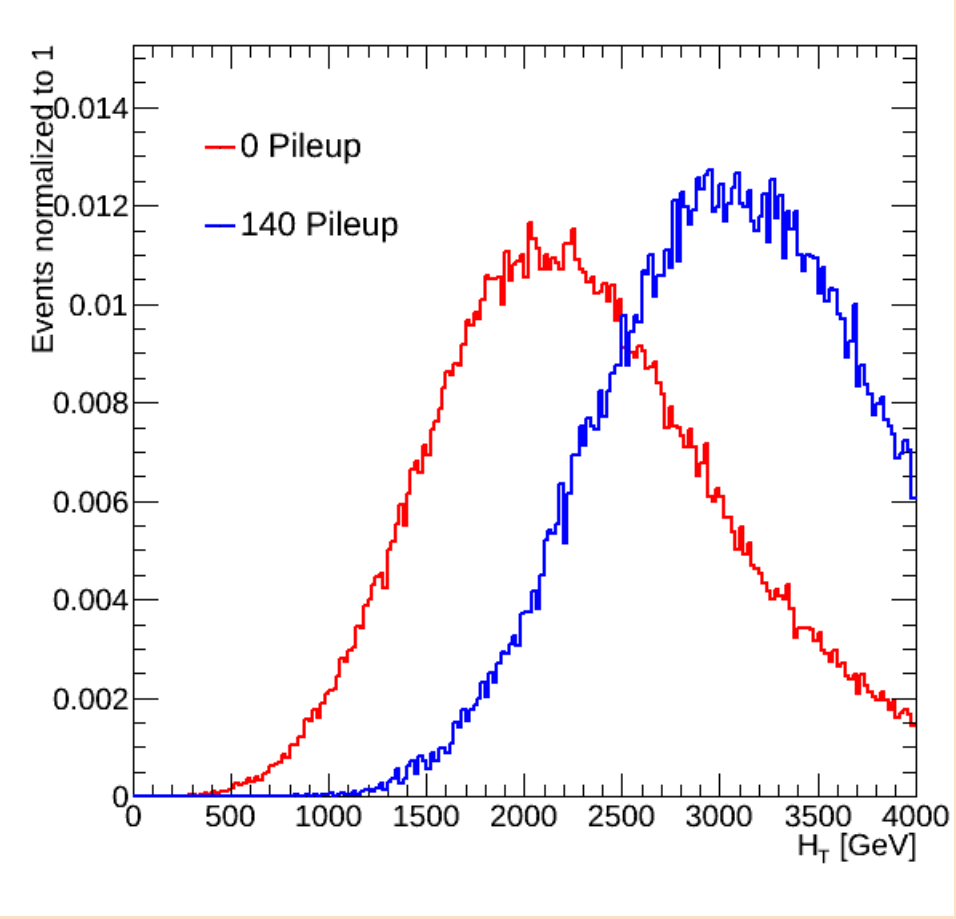
Effect of Pileup (33 TeV, M = 1300 GeV)





- Using pileup subtraction
- Effect on shape of leading objects is small

Pileup and H_T (33 TeV, M = 1300 GeV)



- Drawbacks:
  - Electron efficiency decreases by 18%
  - Muon efficiency by 20%
  - Pileup subtraction is not perfect
- This is preliminary
  - Better subtraction scheme for jets once Delphes parameters are finalized

Conclusion

- First look at top partner with charge 5e/3 at 33 TeV and 13 TeV
- Search is feasible
- Next steps:
  - Finalize Delphes parametrization
    - Pileup subtraction will be improved
  - Jet substructure in Delphes
  - Generate same-sign backgrounds
- Thanks to S. Padhi, M. Slyz, J. Stupak and everyone from snowmass-ef-cern